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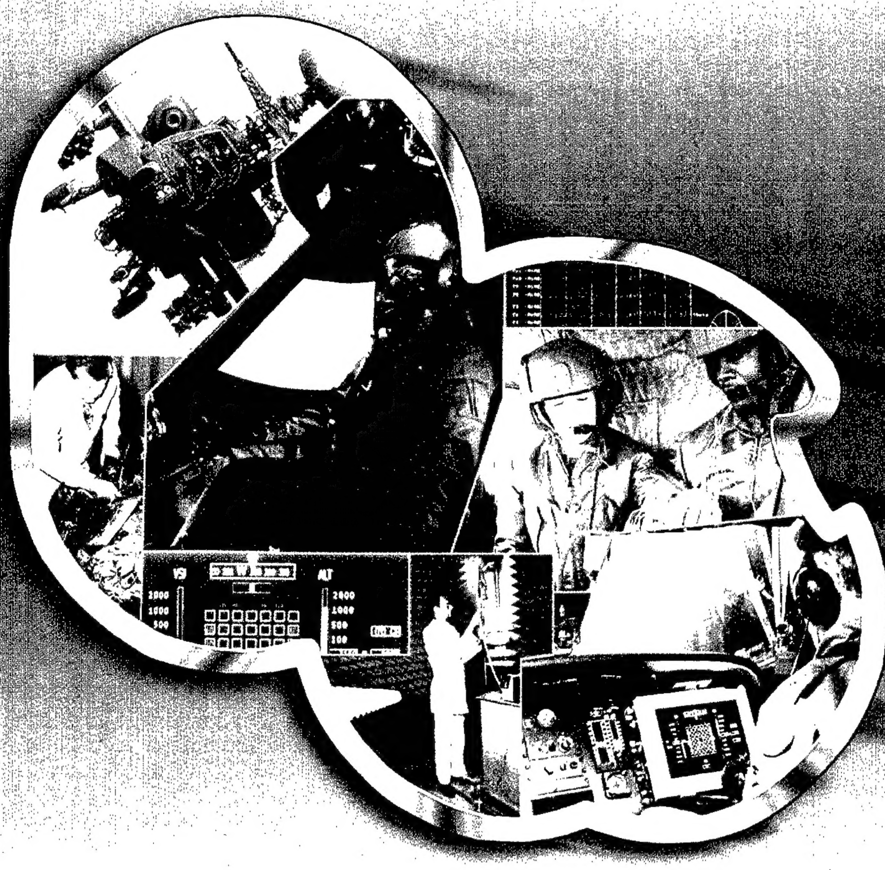
Issues in Design and Safety of Helmet-Mounted Displays – Results of a Rotary-Wing Pilot Survey

by Joanna L. Greig, Siobhan M. Gallagher, Shannen L. Dunkin, Mary E. Brock, and Patricia A. LeDuc



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13. ABSTRACT *(Maximum 200 words)*
An internet-based questionnaire study developed by researchers at the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, was conducted to address issues in design of the Aviator's Night Vision Imaging System Head-Up Display (ANVIS/HUD) and Optical Display Assembly (ODA) systems. Survey responses analyzed included those regarding structural and display design, as well as those addressing issues concerning flight safety. Survey participants included active duty, reserve, and National Guard, as well as Department of the Army civilian pilots, from units around the world responding to the questionnaire between January and July 2002. Data abstracted from open-ended questionnaire results were transformed into binary variables for analytical purposes. Approximately 32 percent of HUD users and 44 percent of ODA users indicated they would not use their HUD or ODA if given the choice. However, the results gathered are essential for directing further testing and evaluation of proposed modifications.

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Table of contents

Page

Introduction........1

Background........1

Methods........2

Results........3

Discussion........11

References........12

Appendix

ANVIS HUD/ODA survey........13

List of figures

1. Percent indicating would use HUD/ODA........4
2. Percent requesting design modifications........5
3. Percent requesting symbology added or removed........7
4. Percent indicating range of symbology brightness control insufficient........8
5. Percent indicating symbology interferes with vision outside the cockpit........9

Introduction

The past three decades of technological advances in U.S. Army aviation have provided the capability to fly nap-of-the-earth (NOE) missions at night. The technology that has enabled Army pilots to gain this operational advantage is the helmet-mounted intensification display device called the Night Vision Goggle (NVG) (Collins, Piccione, 1998). Further workload requirements have led to the production of the Head-Up Display (HUD) as well as the Aviator's Night Vision Imaging System (ANVIS), a current version of the NVG. The HUD superimposes flight symbology on one tube of the ANVIS so that no head movement is required to obtain flight information. Overall, this addition has allowed aviators to minimize workload during flight. However, previous research has shown that some aviators have experienced enhanced spatial disorientation while using the HUD during combat and noncombat flights (Durnford et al., 1995). In addition, reports from aviators in the field have raised other issues in design of the ANVIS/HUD with respect to flight safety.

Background

The ANVIS/HUD is an image intensification device mounted on current Army helmets of both UH-60 and CH-47 pilots. It provides specific night vision imaging capabilities in concert with specific flight symbology. The symbology enables the pilot to assess flight parameters without having to look "inside" the cockpit and assists them in remaining focused on aircraft direction. Similar helmet-mounted displays used solely by OH-58D pilots are known as Optical Display Assemblies, or ODA's.

The unpredictability of spatial disorientation combined with the stress of night operations in the NOE flight regime makes it necessary to determine the experience aviators have had in using ANVIS/HUD or ODA's and the suggestions they may have for design modifications to enhance capabilities during military operations. This is needed before the U.S. Army Aeromedical Research Laboratory (USAARL) can develop research aimed at improving design of the HUD. Information from aviation units will assist in directing appropriate research that will also benefit the aviation community through enhanced training and/or technological changes. A brief questionnaire was administered to assess aviator experiences in using the ANVIS/HUD or ODA assembly.

Methods

Procedure

A questionnaire consisting of both quantitative and subjective, open-ended questions was incorporated. Survey responses presented in this report specifically addressed HUD and ODA design issues revealed within the quantitative responses, as well as safety issues provided by responses within the open-ended questions. Data abstracted from open-ended questionnaire results were transformed into binary variables for analytical purposes.

Subjects

Questionnaire respondents included all personnel completing the internet-based survey. Respondents were directed to the survey website through advertisements within aviation periodicals and telephone solicitations to units. Survey responses were obtained from active duty, reserve, and National Guard, as well as Department of the Army civilian pilots from units around the world.

Instrument

The instrument for study (Appendix) was an internet-based platform administered from January through July 2002. This survey was designed specifically to address issues in the design of ANVIS/HUD and ODA systems developed by the researchers at USAARL, Fort Rucker, Alabama. Survey responses analyzed included those regarding structural and display design, as well as issues revealed in open-ended questions concerning flight safety. Due to a computer error during the storage procedure, data for questions 5-8 were rendered unusable for analyses. Additional questions regarding spatial disorientation were reserved for subsequent analyses.

Design issues

Questions regarding design focused on both structural and display issues. Aviators were asked if any design modifications should be made to their device. Additional space was provided for respondents to list and explain such suggested structural modifications for both the HUD and ODA systems.

Questions specifically addressing issues of display design asked aviators about such things as the range of brightness control and symbology. Respondents were queried on the sufficiency of range of brightness control, how frequently they had to adjust the brightness, as well as whether the symbology interfered with their vision outside of the cockpit. Participants were asked if any symbology should be added or removed from the display, and were directed to list and explain such alterations to the display symbology.

Flight safety issues

Issues in flight safety were revealed within the responses provided by the aviators within the open-ended questions. As the survey participants listed their structural or design modifications, reasons cited for such changes often included perceived issues and concerns regarding flight safety.

Data analyses

Descriptive analyses consisting of frequency distributions of selected demographic and flight characteristics were performed. Data were summarized as means with standard deviations where appropriate. Data abstracted from open-ended questionnaire results were transformed into binary variables for analytical purposes. Univariate analyses illustrating differences between means of continuous variables and categorical variables between HUD and ODA users were performed using t- and chi-square tests, respectively. Participants reported additional problems, design modifications, and suggested symbology changes for use of the ANVIS/HUD or ODA display. Results were stratified by aircraft type and ANVIS/HUD versus ODA users.

Results

Demographics

Survey respondent demographics obtained from the questionnaire are provided in the table below. The majority of study participants were HUD users.

Table
Population demographic characteristics.

Aviator Characteristic	Overall	HUD	ODA
Total	404	241	163
Aircraft			
CH-47	26	26	--
UH-60	215	215	--
OH-58	163	--	163
Mean flight hours (SD)	2204 (2092)	2517(2290)	1741(1661)
Mean NVD hours (SD)	478 (500)	496(548)	454(421)
Mean HUD/ODA hours (SD)	71 (92)	70(86)	73(100)

Design issues

Although the majority of respondents (257 or 63 percent) indicated that they would use their display if given the option, 76 or 32 percent of HUD users and 71 or 44 percent of ODA users indicated they would not use their display device if they were given the option (Figure 1). The following text outlines their reasons for this and their suggested modifications.

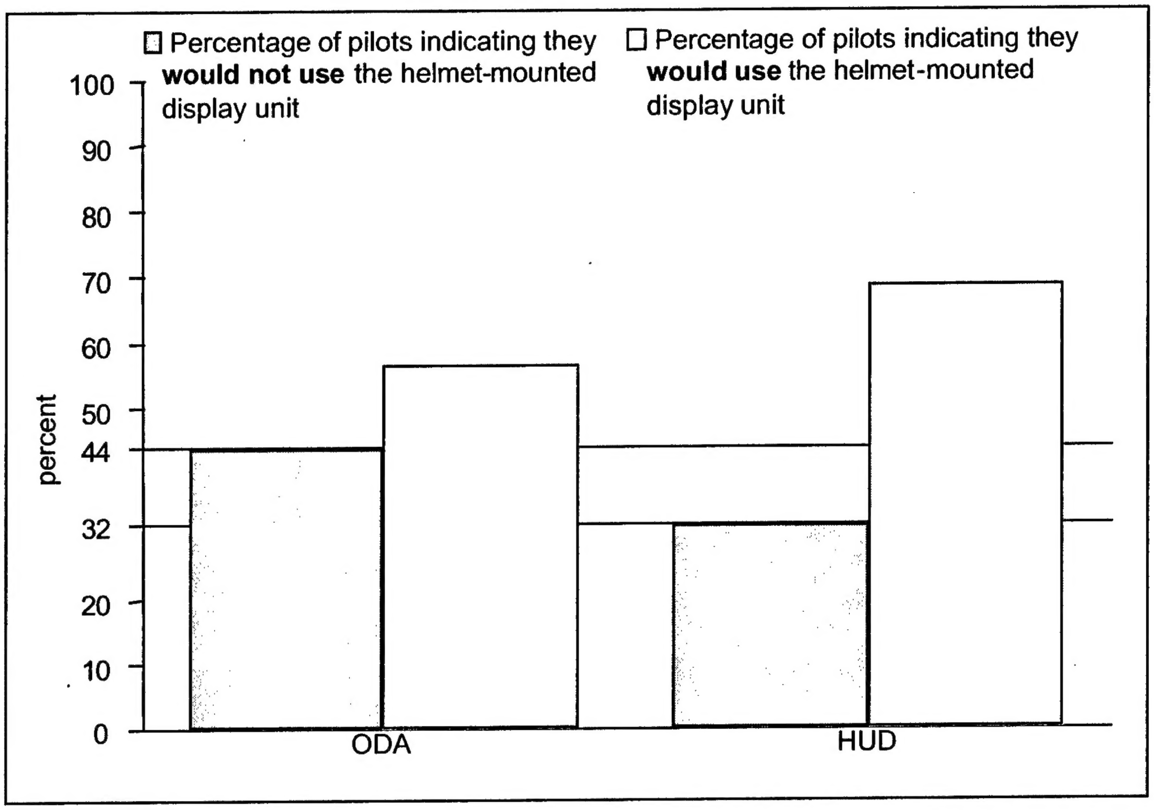

Figure 1. Percent indicating they would use the HUD/ODA.

Structural suggestions for ANVIS/HUD and ODA

A total of 272 (68 percent) of survey participants indicated that design modifications should be made to their display devices (Figure 2). The majority, 175 (64 percent) of these were HUD users, while 97 (36 percent) of those desiring design modifications were ODA users.

Size and weight

Reasons for the necessity of modifications in design were provided by handwritten responses within the open-ended questions. Many of the survey respondents indicated the necessity of a more lightweight, much smaller or less bulky design of their display devices. Approximately 17 percent of all survey respondents revealed a need for a lighter display. A statistically significantly higher proportion ($p = 0.00$) of HUD than ODA users (26 versus 5

percent, respectively) provided written information within the survey indicating the necessity for a more lightweight device.

Actual survey responses with respect to this topic included, "*the weight and bulkiness is the main issue that needs to be corrected*" and "*The weight of the HUD needs to be reduced to prevent fatigue on the pilot.*"

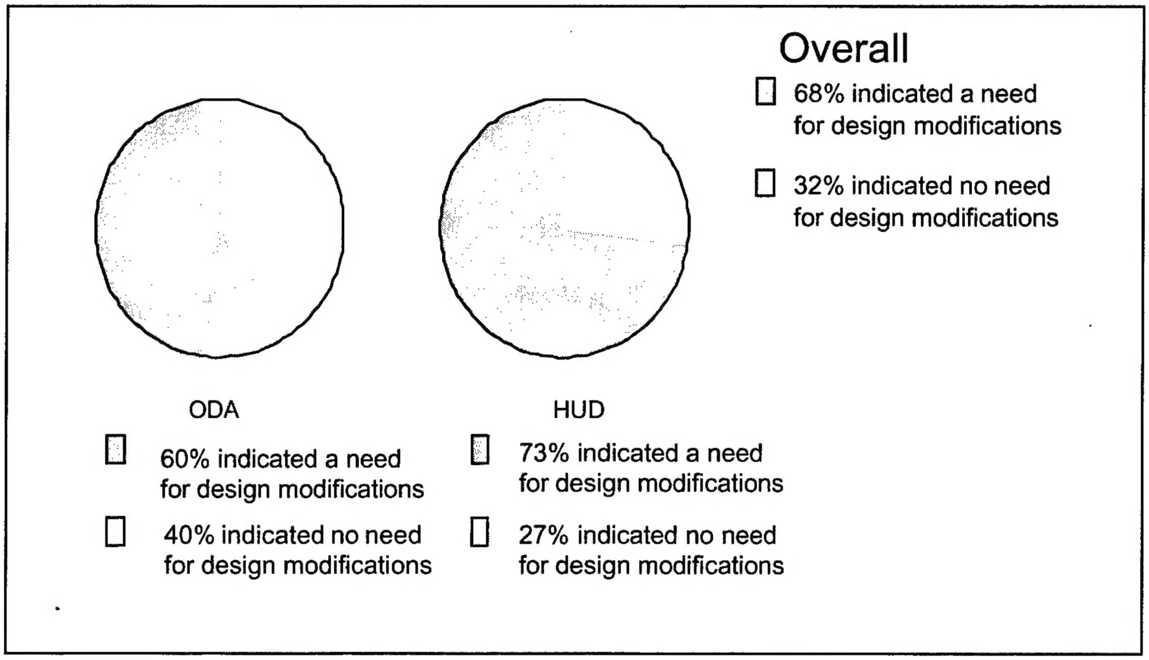

Figure 2. Percent requesting design modifications.

Cable

Additionally, survey respondents indicated a need for design modifications of their display device's cable. Aviators called for smaller, lighter cables and HUD users asked for more flexible cords. A total of 164 (41 percent) of survey respondents indicated a problem with the cable within the open-ended questions. HUD users cited safety issues within the written responses with regard to cables, which are detailed within the sections below.

Repairs

Pilots indicated within their written responses that they experienced difficulty with repairing their display device. They explained their devices often broke easily and were not repaired in a timely manner. Twenty-two (5 percent of pilots surveyed) indicated experiencing such problems, including 8 (3 percent) HUD users and 14 (9 percent) ODA users. Eighteen (4 percent of pilots surveyed) indicated that their display device was often broken, including 7 (3 percent) HUD users and 11 (7 percent) ODA users. Twelve pilots (3 percent) indicated

difficulties getting timely service of their device. Of these, 6 (3 percent) were HUD users and 6 (4 percent) had ODA devices.

Actual written responses from ODA users included, *"Very weak construction. Breaks easily...repair parts/basic repairs are hard to get/find," "Our troop's readiness rate is approximately 50 percent, with some ODA's being inoperable for 3 years," "ODA's have clip fasteners that break pretty easily,"* and *"Problem with ODA's is maintenance...Turn around for maintenance in overseas units was typically 6-8 months for repairs."* Responses from HUD users included, *"Our devices are frequently partially inoperative. One side or the other will have one or multiple malfunctions," "There are numerous maintenance problems with the HUD and there aren't enough HUD qualified "spark chasers" to fix the problems," "...the pins...on the cannon plugs... are getting bent or pushed in...Still having problems with the clamp screws backing out," "Multiple card failures are now occurring with the HUD,"* and *"The biggest problem my unit is having is trying to get the HUD's fixed."*

<u>Suggested display improvements</u>

Although the majority of aviators surveyed indicated no need for any symbology to be added or removed from their device, a total of 94 (23 percent) pilots surveyed indicated the need for changes in the symbology of their device (Figure 3). Of these pilots, the majority, 63 (67 percent), were HUD users.

Weapon symbology

A total of 24 (15 percent) ODA pilot survey participants indicated the need for additional symbology on their display representing aircraft weapons operations. ODA pilots indicated that such an addition to their display devices would allow them to maintain their attention on their display device without having to look into the cockpit. Some mentioned their concern in having to focus their attention inside the cockpit at night and indicated they preferred keeping their attention outside during night operations involving the firing of weapons.

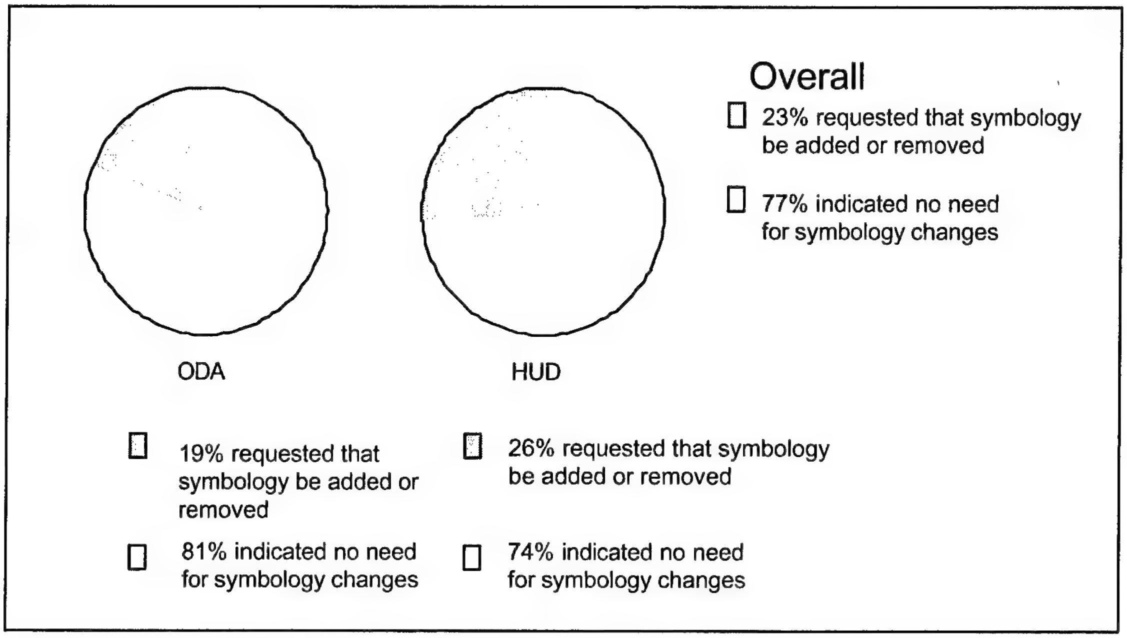

Figure 3. Percent requesting that symbology be added or removed.

Range of symbology brightness control

A number of survey participants (86 or 21 percent) indicated that the range of symbology brightness control was not sufficient with their display device (Figure 4). A total of 25, or 10 percent of HUD users within this survey, indicated the range of brightness control was not sufficient. A total of 61 (37 percent) of ODA users also indicated their range of brightness control was not sufficient. The majority of pilots (264 or 65 percent of survey respondents) also indicated that they frequently had to adjust the brightness of their symbology. A total of 170 (64 percent) of these pilots were HUD users, while 94 (36 percent) were ODA users.

A total of 45 pilots (11 percent) reported dissatisfaction with the brightness of symbology within their display device in the open-ended questions. A statistically significantly ($p = 0.00$) greater proportion of ODA users than HUD users (33 or 20 percent versus 12 or 5 percent, respectively) mentioned a need for an improved dimming or brightness control, with some ODA pilots indicating the need for a rheostat control of brightness, rather than the pre-determined settings available. Such issues were seen as a potential compromise in flight safety for many of the pilots, as is discussed below.

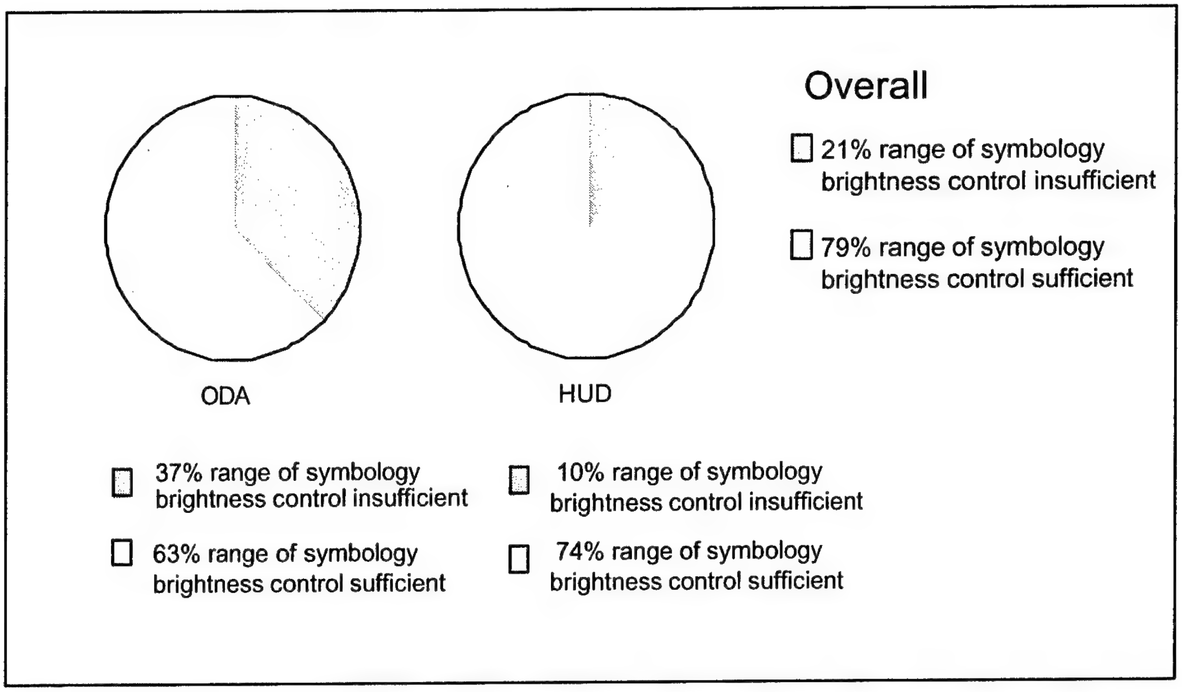

Figure 4. Percent indicating range of symbology brightness control insufficient.

Display pages

Many pilots expressed a need for fewer display pages or more display information provided on one screen. Although only a total of eight mentioned this need within any one of the open-ended response options, all eight pilots were HUD users. Such issues with multiple pages required to get through prior to reaching the display of interest may be revealed as a more common complaint in future surveys designed specifically to examine such an issue.

Programming time

Twenty-one (9 percent) of HUD pilots indicated within the hand-written responses that the time involved in programming their display devices was too long for expedited flight operations. Again, although none of the ODA pilots mentioned this, such an issue might also be revealed as a more common issue among all pilots in future surveys designed more specifically to examine such an issue.

Actual responses from the pilots surveyed included, *"Programming the HUD's eight pages of data is not necessary or practical," "It takes too long to program the HUD...in a medevac unit [which] cannot afford to waste time programming peripheral devices...," "having eight pages to program and scroll through is too complicated"* and *"our aviators prefer not to use HUD...it takes too long to program."*

Vision interference

A total of 98 (24 percent) pilots surveyed responded that at some time the symbology of their display device interfered with their vision outside of the cockpit. A total of 53 (54 percent) of these responders were HUD users. Although the majority of both HUD and ODA users indicated that the symbology did not interfere with their vision outside the cockpit, 45 (28 percent) ODA users and 53 (22 percent) HUD users indicated that it had interfered with their vision at some time (Figure 5). Pilots also often wrote that the brightness of the display was often too bright for night operations. Written questionnaire responses suggested potential compromises in safety in the time necessary to adjust their vision from the bright display to visualize their position outside the cockpit.

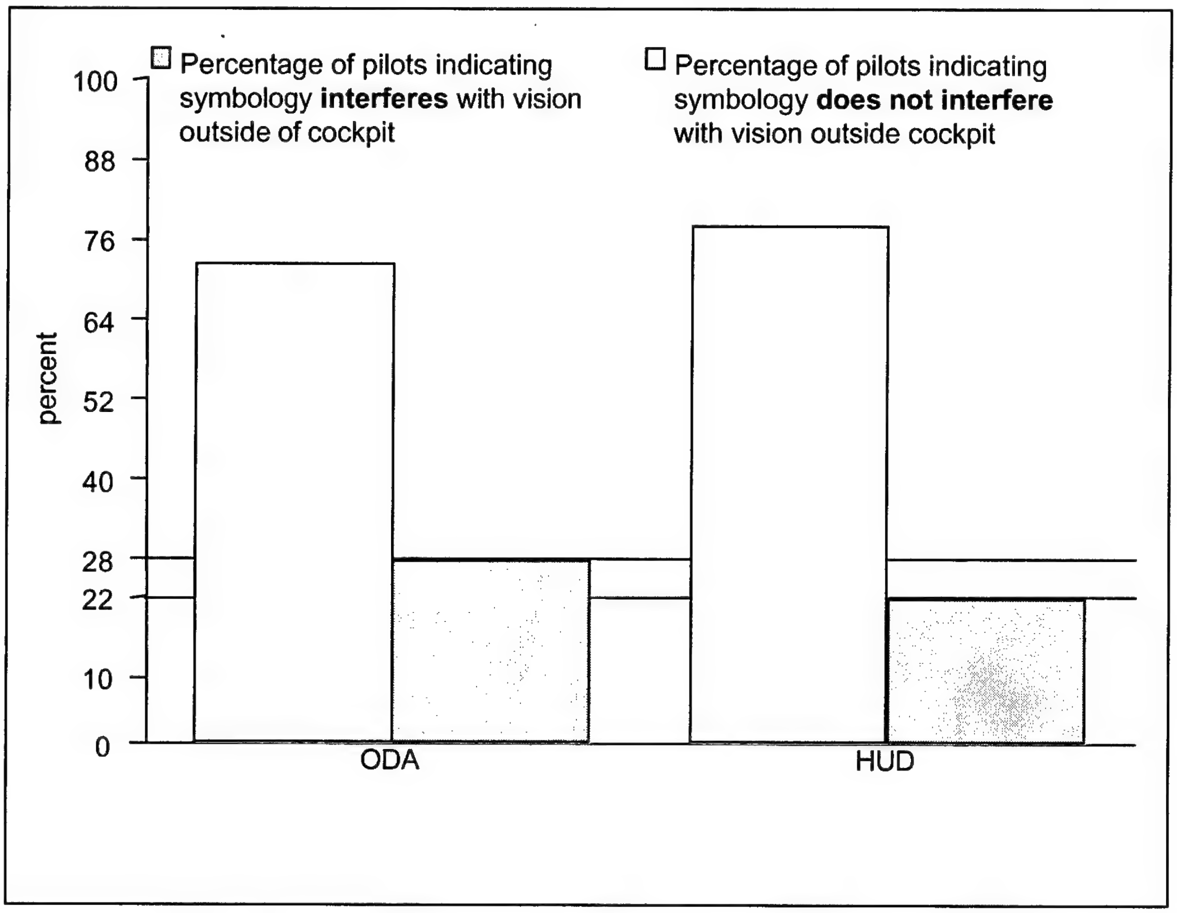

Figure 5. Percent indicating symbology interferes with vision outside the cockpit.

Actual written responses with respect to vision interference with HUD use included, "*I have found the drift velocity vector…and vertical speed indicator…to be distracting if not dangerous*" and "*the velocity vector is a distraction.*"

Written responses regarding brightness of the HUD display included, "*The brightness switch on the UH-60 collective is not "gated" well enough. It is easy to accidentally scroll through pages while attempting to brighten or dim,*" and "*The brightness of the HUD cannot compensate for bright lights and therefore is bleached out when the aircraft is turned toward a shoreline with lights.*" *ODA users wrote, "the lowest brightness setting is still too bright for zero-illumination night operations in a desert or over-water environment,*" "*…make settings dimmer for zero illumination—too bright even on lowest setting.*"

Display lag time

Many (16 pilots, or 7 percent) of the HUD users expressed a concern for the lag time involved in their displays. Pilots explained that there was a brief period of time before their display provided the information on altimeter readings. This was often explained as presenting a safety issue.

HUD users indicated this design issue in comments such as, "*faster updates needed," "radar altimeter lags…it is useless when we need it," "the aircraft radar altimeter has a lag time to the aircraft instrument panel…I still have to cross check the aircraft instruments," "[there is a need for a] pressure altimeter which updates automatically," and "the software installed needs to be without lag to the actions occurring in the cockpit.*"

Egress

Safety was a concern for many survey respondents indicating the need for design changes for the cable connections of their display wires. In addition to the above mentioned safety issues in device size or bulkiness, multiple pages to flip through, programming time and lag time, many pilots were concerned that the cable connection for their display device was not readily detachable and would present a potential hazard in times of need for a quick egress.

A total of 19 pilots or 5 percent of all survey participants wrote of their concerns for ease of egress in an adverse event. Fifteen (9 percent) ODA users expressed this concern. A statistically significant ($p = 0.00$) greater percent of ODA than HUD users indicated such a concern for egress issues with their display device's cable connection. A total of 36 respondents or 9 percent of all survey participants actually suggested the need for modification to a *cableless* display system platform.

Questionnaire responses regarding safety concerns with the cable for ODA display devices included, "*…the cord is rather large and cumbersome—it gets in the way of head movement," "…too many wires in cockpit…," "remove the wire," "[a reduction in wires would] prevent spaghetti head"* and *"the ability to rapidly egress the aircraft is a main concern."*

Discussion

Results from this survey have potentially important implications for design modifications of the ANVIS/HUD and ODA display devices, as well as flight safety.

Although many of the survey responses were gathered from open-ended questions, the results of such handwritten responses call for a focus on issues in display design for functional flight operations. Pilots using the HUD indicated the necessity of a more lightweight design which required less programming time. Both HUD and ODA users also indicated concerns for safety in specific operational situations with regards to display brightness within these responses. Although further research is needed to assess the actual proportions of pilots desiring such modifications, the results gathered are essential for directing further testing and evaluation of proposed and current modifications.

With the reported 32 percent of HUD users and 44 percent of ODA users indicating they would not use their HUD or ODA if given the choice, and 68 percent of the pilots who responded to the survey indicating the need for design modifications of their helmet-mounted device, the responses outlined within this report cannot be ignored. However, responses to this survey were gathered from January through July of 2002. As such, it is important to note that at the time of this writing, some of the design flaws within the display devices have since been corrected. For instance, the original display lag time, which was at least three-tenths of a second for both the radar altimeter as well as the barometric altimeter, has now been corrected to less than eighty milliseconds within the new version of the HUD display. Additional refining of display symbology brightness has also been introduced. It is not possible to accurately assess to what extent many of the responses came from individuals who had not flown with such display devices since the introduction of these improvements. However, further research might still focus upon identifying and more accurately quantifying the remaining issues, such as display symbology or safety, reported within the open-ended questions.

References

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Durnford, S.J., Crowley, J.S., Rosado, N.R., Harper, J., and Deroche, S. 1995. Spatial disorientation: A survey of U.S. Army helicopter accidents 1987-1992, Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 95-25.

Appendix

ANVIS HUD/ODA survey

If you have ever used ANVIS HUD/ODA, please answer the following questions.

1. How many total flight hours do you have? ___________
2. Are you HUD/ODA qualified? Y N
3. How many NVD hours do you have? ___________
4. Approximately how many hours have you used HUD/ODA? ___________
5. Does your unit use HUD/ODA? Y N
6. Is HUD/ODA training a requirement of your aircrew training program? Y N
7. How regularly do you use HUD/ODA ? Please circle one answer.

    a. each NVG flight.
    b. only when required for a specific mission.
    c. at a minimum to meet ATP requirements.
    d. other, please specify. ____

8. How often do you feel that you need to use HUD/ODA to remain proficient? Circle one.
    a. once a week. b. once a month.
    c. once a year. d. other, please specify. ______________________________

9. In which aircraft do/have you use/used HUD/ODA? ______________________________
10. If applicable, how many estimated minutes does it take for you to program HUD? ______
12. On which eye do you use HUD/ODA? Circle: (right only), (left only), (opposite seat side), (same as seat side), (no specific eye or side consideration).
13. Do you frequently have to adjust the brightness of the symbology? Y N
14. Is the range of brightness control sufficient? Y N
15. Does the symbology interfere with your vision outside the cockpit? Y N
16. Have you ever entered IMC when using HUD/ODA? Y N
17. If yes for #15, did you use (a) the HUD/ODA to recover or (b) the cockpit instruments?
18. Given the option would you use HUD/ODA? Y N If no, please explain.
19. Should any symbology be permanently added or removed from the display? Y N
    If yes, please list. Added Removed
20. Should any design modifications be made to HUD/ODA? Please list.
    HUD ODA